European Centre of Excellence

in

Microwave, Millimetre Wave and Optical Devices, based on Micro-Electro-Mechanical Systems (MEMS) for Advanced Communication Systems and Sensors (MIMOMEMS)

Coordinator: Dr. Alexandru Müller, alexandru.muller@imt.ro

Project financed (2008-2010) through the "Regional potential" part of the European Framework Programme - FP7

Capacities - Part 4 - Research Potential.
Activity: 4.1.Unlocking and developing the research potential in the EU´s convergence regions and outermost regions (REGPOT-2007-1)

We have selected new niche research topics from the areas of RF-MEMS and Optical-MEMS taking into account the latest trends in microsystems technology and priorities for long term research that have been identified by the EU technology platforms - ENIAC, Photonics21, and EPOSS - and included in FP7 ICT Work Program.

Two IMT- Bucharest laboratories, for RF-MEMS and Microphotonics, respectively, already active in previous European programmes, have joint their efforts to achieve this excellence centre.

Previous and present of European cooperation of the two IMT- Bucharest laboratories.

- *The Laboratory of RF-MEMS* has coordinated one of the first European projects in RF-MEMS:

- Micromachined Circuits for Microwave and Millimetre Wave Applications (MEMSWAVE, 1998-2001, FP4-INCO); coordinator: Dr. Alexandru Müller, alexandru.muller@imt.ro, IMT-Bucharest. The project was nominated in 2002 among the top ten European projects for the Descartes Prize (awarded for the best European co-operative research projects). Also, the RF-MEMS Laboratory was a key partner in theFP6 NoE

-RF-MEMS “Advanced MEMS for RF and Millimetre Wave Communications” (AMICOM, 2004-2007 FP6 NoE), a

and is also involved in the recently approved FP7 STREP

-MEMS 4 MMIC FP7 STREP (2008-2011) call ICT-2007-2.

- *IMT’s Laboratory of Microphotonics* (Dr. Dana Cristea, dana.cristea@imt.ro) was also participating in several FP6 projects:

-Waferbonding and Active Passive Integration Technology and Implementation (WAPITI, STREP, 2004-2007, FP6-IST);

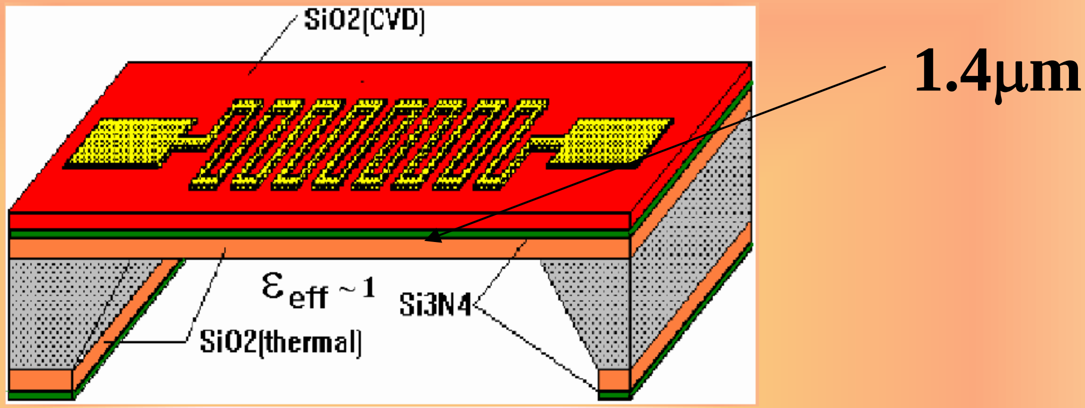
-Multi-Material Micro Manufacture: Technologies and Applications (4M, NoE, 2004-2008, FP6-NMP);

-Advanced Handling and Assembly in Microtechnology (ASSEMIC, Marie Curie Action, 2004-2007, FP6-Mobility),

and it is now involved in the FP 7 Integrated Project

-FlexPAET (2008-2010), FP7 IP call NMP-2007-1.

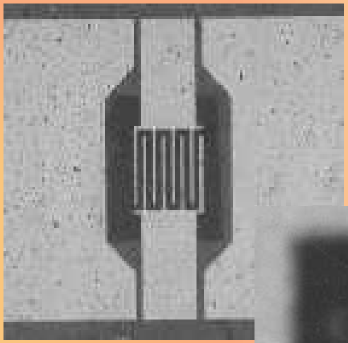
Why membrane supported millimeter wave circuits?

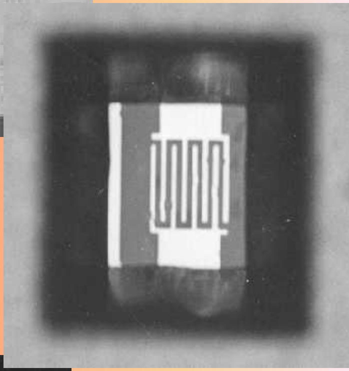


Advantages of membrane-supported passive circuit elements

- reduction of losses due to the dielectric substrate
- reduction of dispersion effects
- the structure looks like being “air suspended” (ε_{eff} ~ 1)
- suppression of unwanted substrate modes
- new features for the design of integrated subsystems

Membrane Supported Circuits for Millimeter Wave Applications





First European results: 1996-1997.

- **IMT Bucharest and CNR Rome**
- **LAAS/CNRS, Toulouse**
- **IRCOM Limoges**

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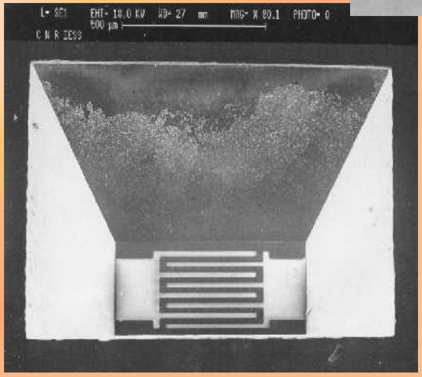


Micromachined Circuits for Microwave and Millimeter Wave Applications
(MEMSWAVE)
Project No.977131
1998 - 2001

IMT-Bucharest (Project coordinator)

Partners:

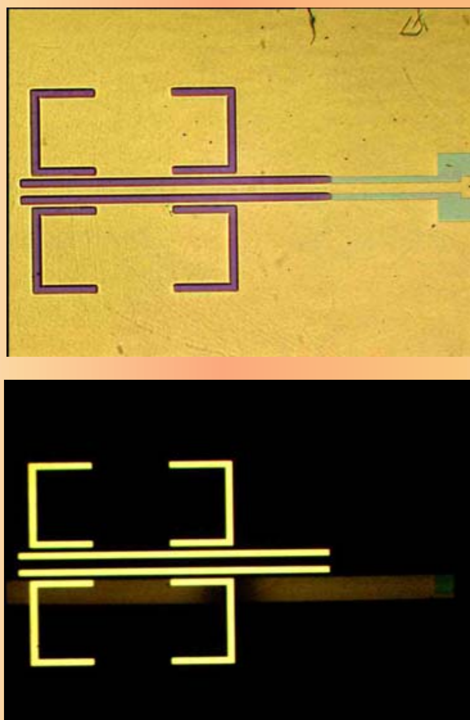
FORTH Heraklion
ITC-IRST Trento
Uppsala University
Tor Vergata Univ. Rome
CNR-M^{2}T Rome
HAS-MFA Budapest
ISP Kiev
Microsensor Kiev Ltd.

TARGETS

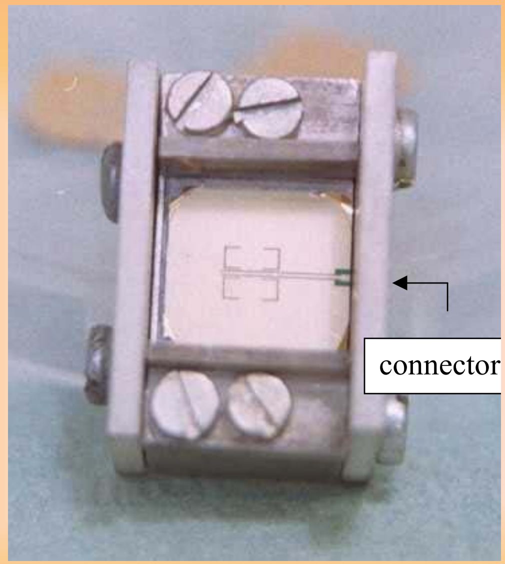
- **Thin dielectric membranes on high resistivity silicon substrate;**
- **GaAs membranes manufacturing;**
- **Micromachined passive circuit elements on silicon and GaAs substrate;**
- **Micromachined millimetre wave band pass filters and antennas;**
- **Receiver modules for 38GHz and 77GHz based on micromachining technology;**
- **Transmitter module for 38GHz.**

The project was nominated between the 10 finalists for the Descartes Prize 2002 of the European Commission

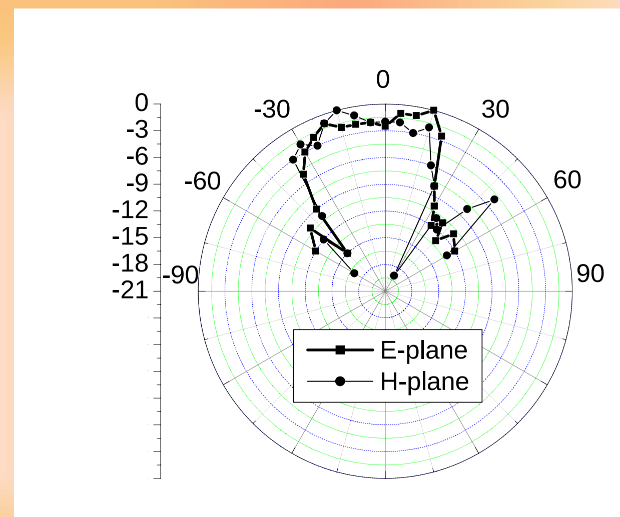
First membrane supported antenna in the MEMSWAVE Project



Top and bottom view (with top illumination)



The antenna mounted in a holder, ready to be measured

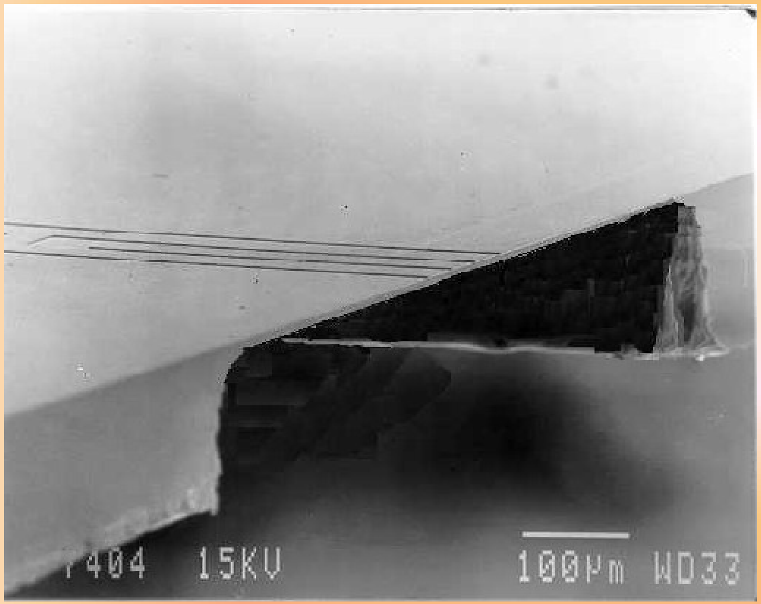


The measured E (bold line) and H (thin line) radiation patterns of the antenna.

IMT- Bucharest , CNR Rome and IRST Trento, 2000

Filter structures on GaAs membranes

IMT Bucharest- FORTH Heraklion in the MEMSWAVE Project -2001



SEM photo of 77 GHz cascaded open end series stubs CPW filter on GaAs membrane

GaAs membrane supported double folded open end series stub band pass filter structure for 38 GHz

Bilateral Cooperations:

FORTH Heraklion

LAAS Toulouse

ITC Trento

HAS Budapest

Tor Vergata University Rome

CNR Rome

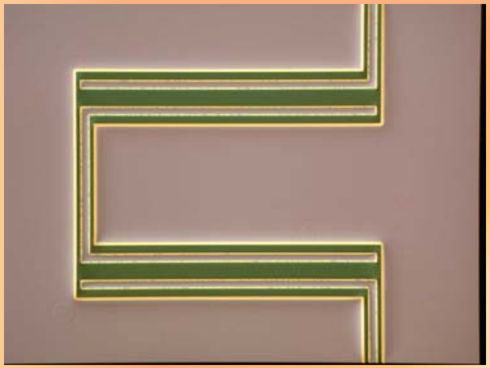
AMICOM -2004-2007

Coordinator – LAAS CNRS Toulouse

CNRS (France) (LAAS-IEMN-IRCOM)

- **CHALMERS (Sweden)**
- **CRANFIELD (United Kingdom)**
- **EPFL (Switzerland)**
- **FORTH (Greece)**
- **IMEC (Belgium)**
- **IMPERIAL COLLEGE (UK)**
- **IMT- Bucharest (Romania)**
- **ITME (Poland)**
- **MILLILAB & VTT (Finland)**
- **PERUGIA (Italy)**
- **TECHNION (Israel)**
- **TEI CRETE (Greece)**
- **TUD (Germany)**
- **TUM (Germany)**
- **ULM (Germany)**
- **UPPSALA (Sweden)**
- **UNIVERSITY OF ATHENS (Greece)**
- **ITC-IRST (Italy)**
- **ARMINES (France)**
- **METU (Turkey)**
- **FRAUNHOFER ISIT (Germany)**
- **FRAUNHOFER IZM (Germany)**
- **TELEMIC (Belgium)**
- **LETI (France)**
- **DIMES (The Netherlands)**

45 GHz Membrane supported filters IMT-LAAS



Top and bottom view

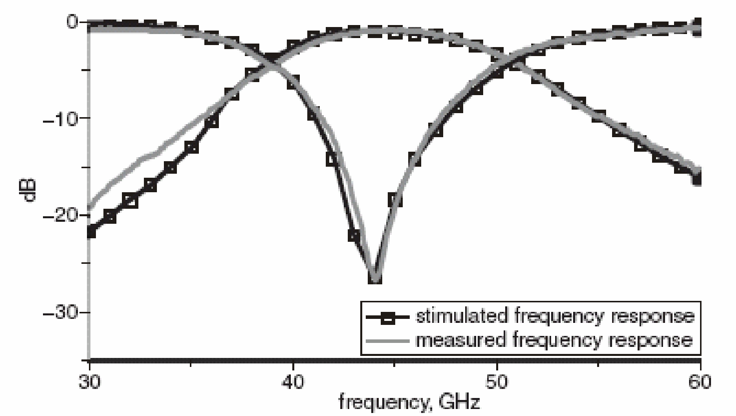
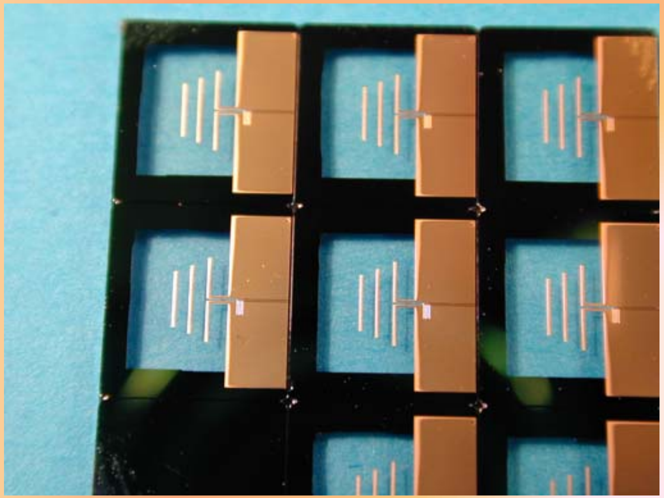
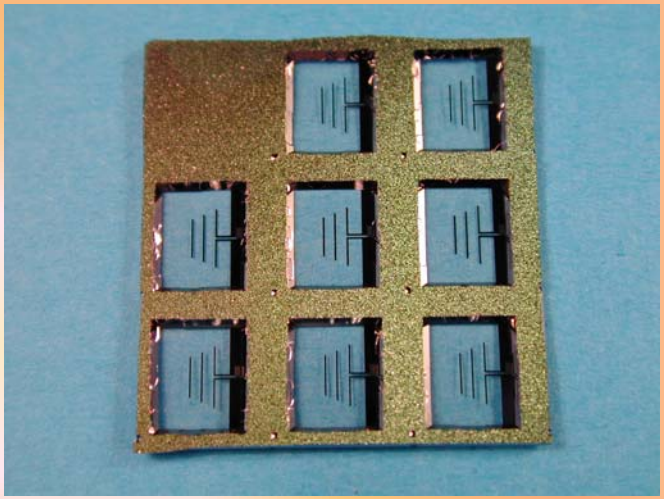


Fig. 3 *Simulated and measured frequency responses for bandpass filter fabricated using silicon micromachining*

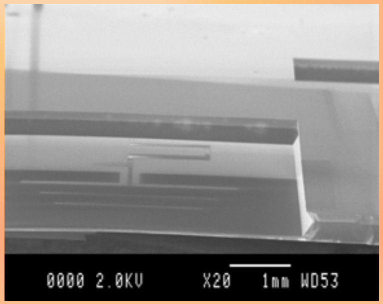
D. Neculoiu, G. Bartolucci, P. Pons, L. Bary, D. Vasilache, A Müller , R. Plana, Electronics Lett, vol 40, pp.180-182, 2004

Yagi antennae structures manufactured using backside etching processing-2003 IMT-LAAS

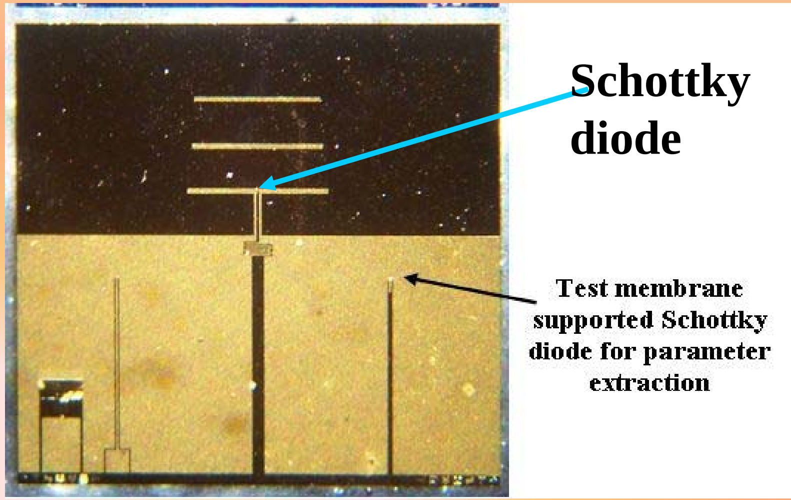


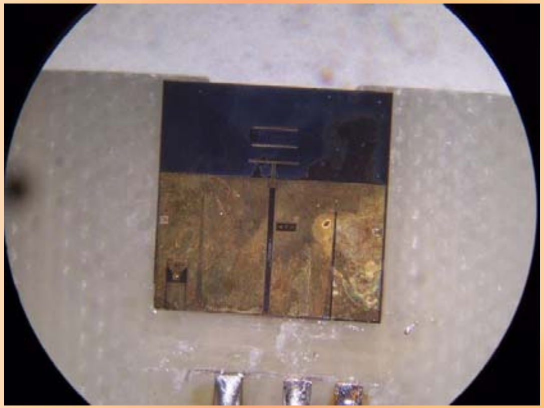


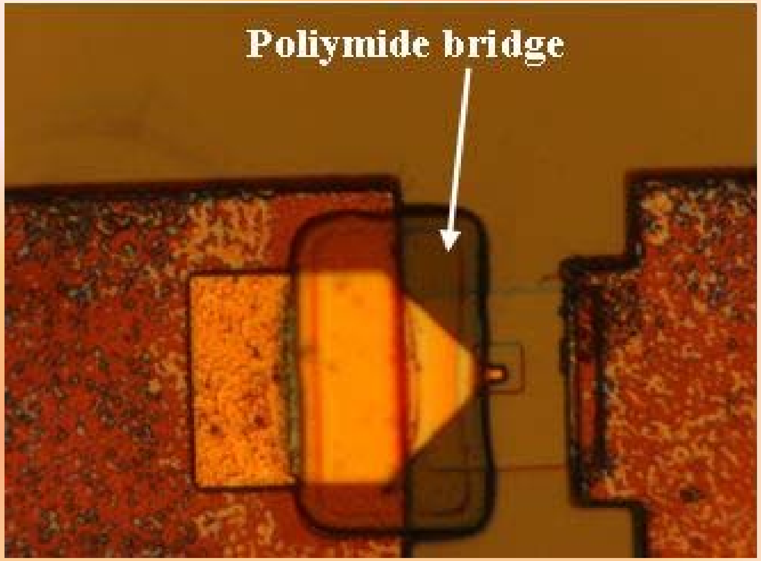
<u>Major advantage</u>: high reproductibility, high yield

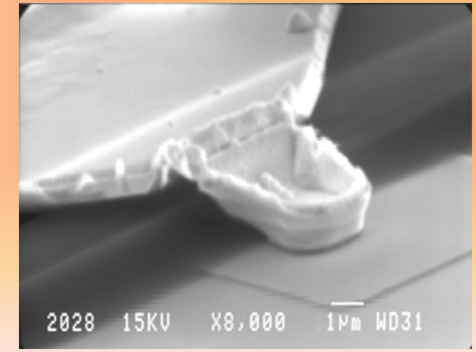


The 60 GHz receiver –GaAs micromachining (IMT-FORTH 2006)



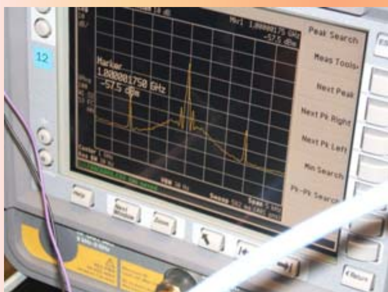




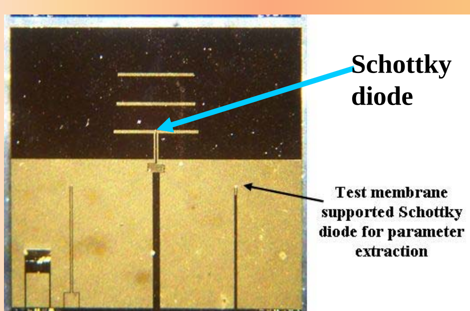


GaAs micromachined 60 GHz Yagi-Uda antennae based receiver used as millimeter wave identification tag

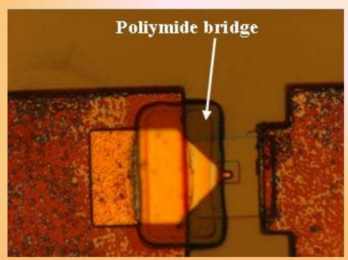
Common work in the frame of the AMICOM Project of IMT Bucharest, FORTH Heraklion, LAAS Toulouse and VTT Helsinki-2007

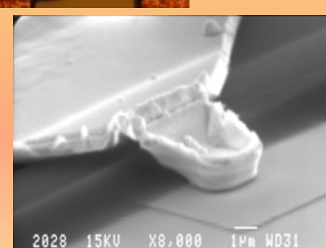


•The MMID concept was demonstrated at distances between 0.5 … 2.5 m
two passive tags:
 -60GHz monolithic integrated micromachined receiver structure with Yagi-Uda antenna
 -77 GHz receiver structure based on the hybrid integration of a membrane supported folded slot antenna with two types of detector diodes (GaAs Schottky diode and InSb based quantum backward diode)

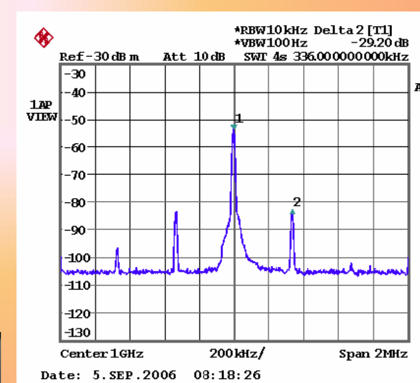


The receiver structure

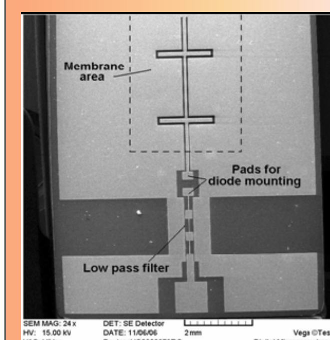




Details of the Schottky diode region

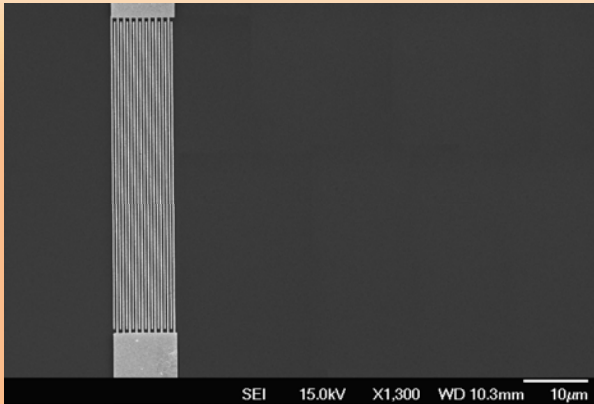


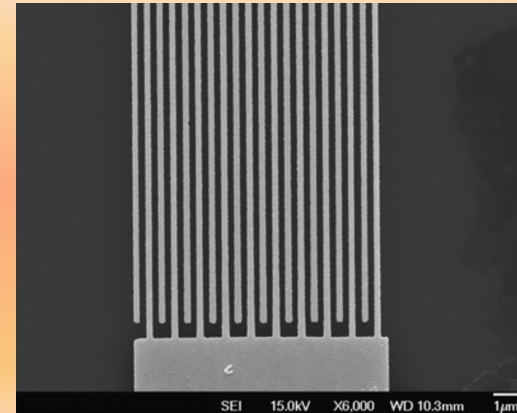
Received backscattered spectrum at a distance of 1.04 m. The transmission power was 34 dBm EIRP.



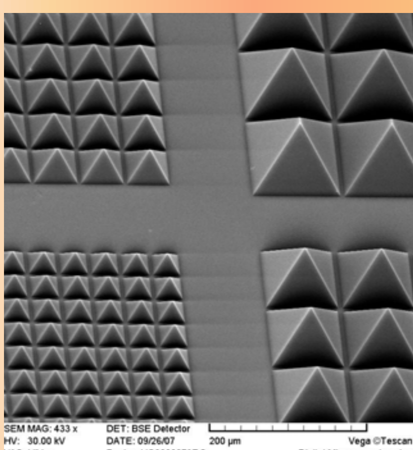
Top SEM photo of the micromachined receiver structure for 77 GHz (before the flip chip detector diode mounting).

FP 7 - MIMOMEMS

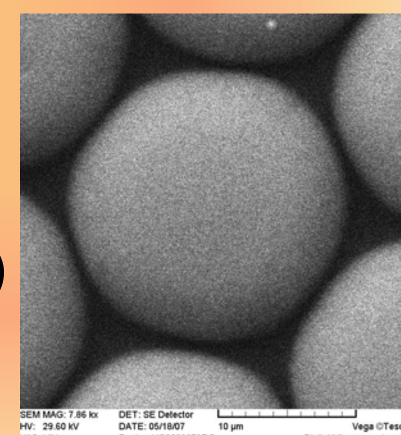




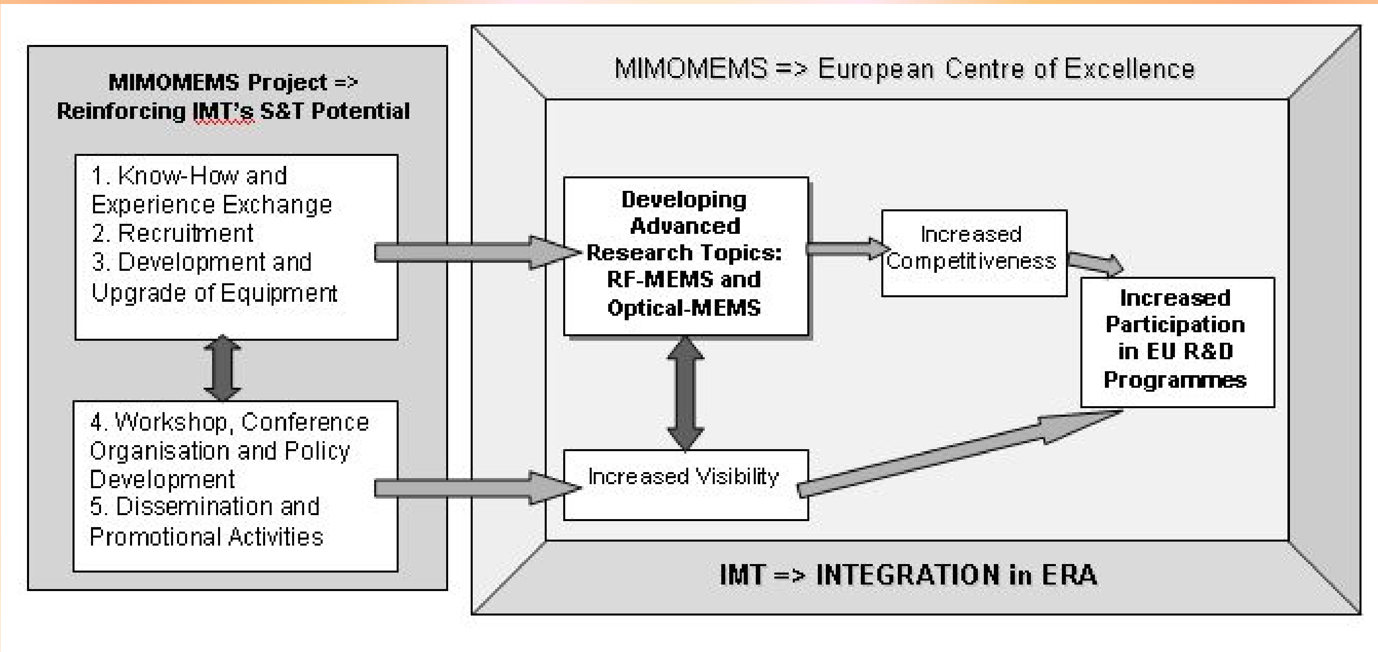
New experimental AlN SAW structure for GHz applications manufactured and measured at IMT-Bucharest . Fingers and pitches with a width on 250 nm have been obtained with the new purchased nanolithographic equipment (Vega-SEM and Elphy Plus EBL) Possible applications in the new generation of mobile phones



Polymer-based diffractive optical elements (DOE) obtained by replication: (left) Polymethyl methacrylate (PMMA) DOEs; (right) Polydimethylsiloxane (PDMS) microlenses



The overall aim of the MIMOMEMS project is to bring the research activity in RF and Optical-MEMS at the National Institute for R&D in Microtechnologies (IMT) to the *highest* European level and create a European Centre of Excellence in Microwave, Millimetre Wave and Optical Devices, based on Micro-Electro-Mechanical Systems (MEMS) for Advanced Communication Systems and Sensors.



Research topics to be developed in the frame of the MIMOMEMS project

A: RF-MEMS

A1. Development of silicon micromachined circuits for microwave and millimetre wave communication systems
A2. Development of GaAs monolithic integrated micromachined receiver modules
A3. Development of Surface Acoustic Wave (SAW) and Bulk Acoustic Wave (BAW) structures on GaN and AlN membranes

B: Optical-MEMS

B1. Heterogeneous integration of silicon and polymer-based micro-photonic devices to improve the functionality and the performance of Optical-MEMS
B2. Sub-wavelength photonic structures for highly integrated optical systems

MIMOMEMS – Objectives (1)

1. Exchange of know-how and experience

The Centre of Excellence will be created by developing IMT's existing scientific expertise and capacities and collaborating closely (twining) with specialist research groups from:

a) LAAS-CNRS Toulouse which has strong expertise in silicon based RF and millimetre wave microsystems, photonic devices, and circuits manufacturing and characterization

b) FORTH-IESL-MRG Heraklion which has excellent knowledge of IIIVs (GaAs and related semiconductors) and wideband gap semiconductor processing (GaN, AlN).

These cooperation will contribute to the development of IMT's Strategic Research Partnerships one of the major objectives (1) of the project.

Cooperation with LAAS-CNRS:

RF MEMS The work together with LAAS-CNRS in their labs will permit high quality technological development and will facilitate the use of latest generation technological facilities (DRIE) for vertical etching profiles of the silicon up to the membrane. We will have also the opportunity to use their microwave characterization facilities up to 110 GHz in the training of the Romanian scientists.

OPTICAL MEMS This topic will provide an excellent opportunity to exploit the complementary expertise of the teams from LAAS-CNRS and IMT in Optical-MEMS. The common research stages, the hands-on training of young researchers from IMT at LAAS-CNRS Toulouse will allow the building of a common team, the optimum exploitation of the research expertise and facilities and the development of advanced devices. The devices will be designed in IMT (with LAAS-CNRS as a consultant), fabricated and tested partly in LAAS-CNRS, and partly in IMT. The twinning with LAAS-CNRS will facilitate the access to a world-class technology facility (silicon processing), and also to the expertise in MOEMS technology and characterisation

Cooperation with FORTH-IESL-MRG

RF MEMS The collaboration in twinning actions with FORTH-IESL-MRG will allow access at the Molecular Beam Epitaxy equipment for GaAs heterostructure growth, as well as for GaAs technological processes. GaAs monolithic integrated micromachined receiver modules will be processed at FORTH-IESL-MRG by IMT together with FORTH-IESL-MRG scientists. Design, mask manufacturing as well as microwave characterization will be performed by IMT. Monolithic integrated micromachined receivers will be manufactured for 60 GHz, 77 GHz and 110 GHz. Collaboration with FORTH-IESL-MRG will permit the growth of metal organic chemical vapour deposition GaN layers on silicon substrate and processing of SAW and BAW structures on GaN and AlN membranes (deep RIE).

MIMOMEMS – Objectives (2)

ii. Increase IMT’s Human Potential

In order to achieve this, Post-Doctoral researchers will be hired with expertise in nanophotonics and microwave millimetre wave devices, and MEMS for advanced communication systems and sensors. Also, experienced researchers will be hired with expertise in exploitation of new equipment.

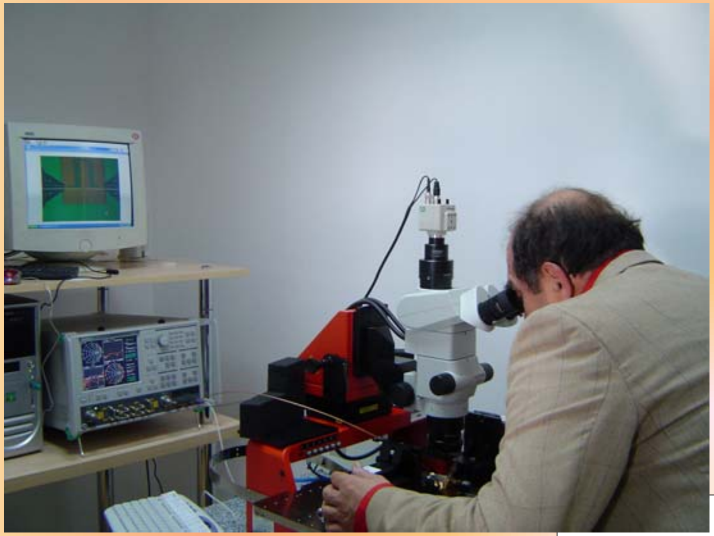
-2 experienced scientists will be hired (for post-docs) using the project budget (starting from the second year). The researchers will be initially hired for 24 month fellowships with 6 monthly reviews. At the end of the period, the researchers will have the possibility to become full time IMT employees.

MIMOMEMS – Objectives (3)

iii. Increase IMT’s Technology Potential

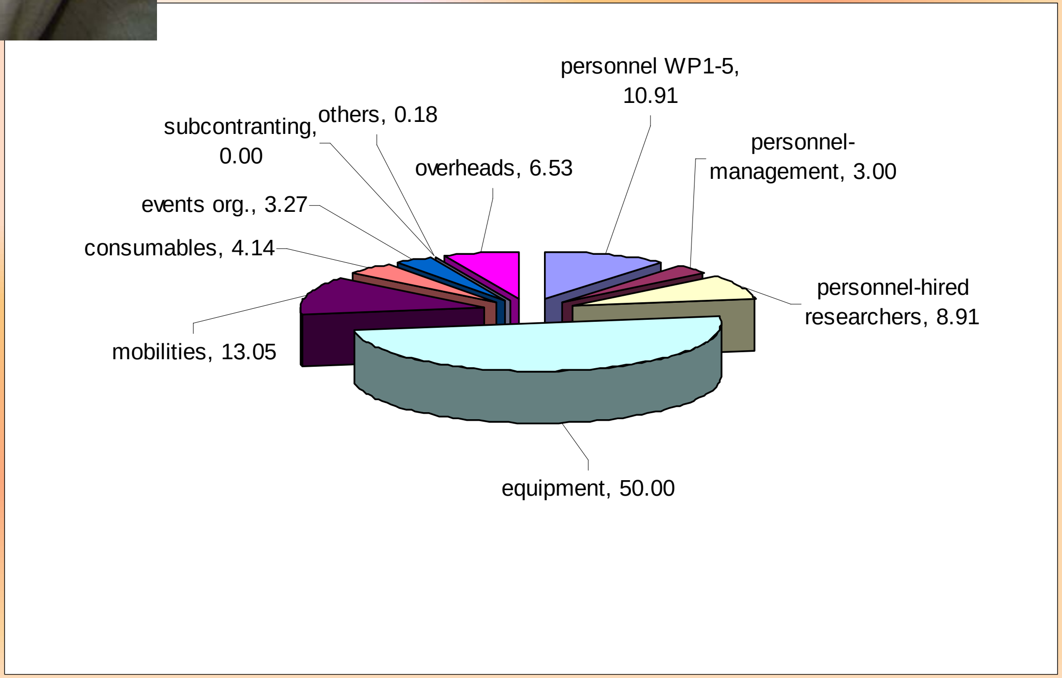
The main objective is to develop IMT’s existing micro-nano facility to be able to move from the micro to the nanoscale wafer characterization and to upgrade to 110GHz the 65 GHz existing set-up for on wafer characterization. This will be done by purchasing new equipment taking into account the latest trends in the development of the research field and training personnel. The proposed new equipments to be purchased by the project are:

- **Near field scanning optical microscope (SNOM)**
- **Upgrade to 110GHz the 1-65 GHz set-up for on wafer characterization**
- **Frequency synthesiser up to 65GHz**
- **Au plating facility for semiconductor wafers**



The new high resolution Raman spectrometer purchased by IMT – Bucharest, in 200,7 in the frame of the National Programme CEEX (Module 4)

The new "on wafer" microwave measurement equipment till 65 GHz purchased by IMT-Bucharest in 2007 in the frame of the National Programme CEEX (Module 4)



MIMOMEMS – Objectives (4)

iv. Increase IMT's Scientific Visibility

The objective is to support knowledge transfer at national and international levels, and facilitate research policy development in the field of RF- and Optical-MEMS.

This will be achieved through IMT's organisation of scientific events, thematic international sessions and seminars. Also, through the organisation of research policy workshops involving researchers, research policy experts and research policy makers from Romania and the EU.

MIMOMEMS – Objectives (5)

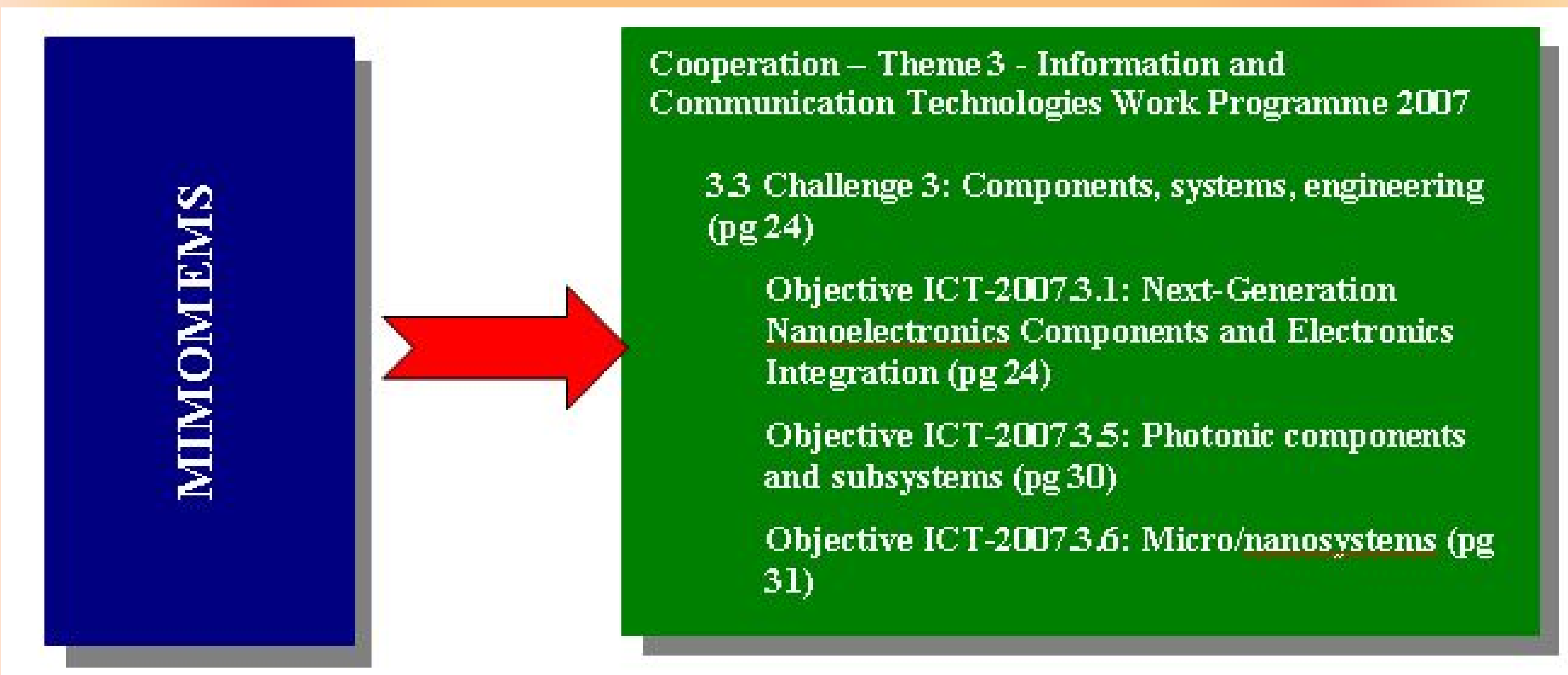
v. Increase IMT's technology transfer for socio-economic needs

The objective is to maximise the transfer and promotion of project results and activities of the MIMOMEMS project in Romania and across the EU.

A multilateral approach will be adopted to achieve this: promotion of project activities and results through a project website; publication of research results in peer reviewed journal and presentation at international conferences; organisation of workshops to make research proposal submissions to relevant calls from the FP7 ICT Work Programme;

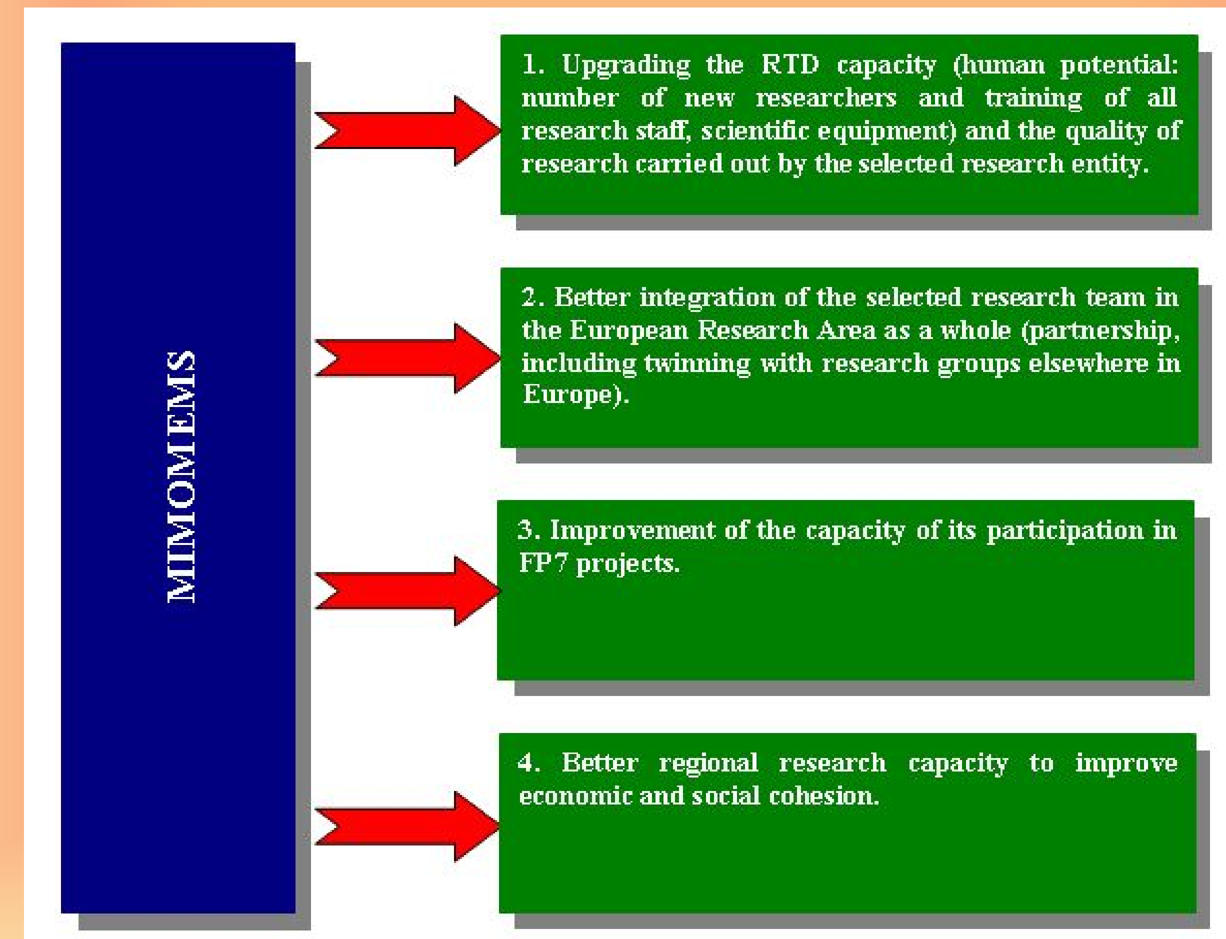
Overview of the areas of the *Capacities - Part 4 - Research Potential Work Programme 2007* that the MIMOMEMS project addresses:

Overview of the areas of the *ICT – Information and Communication Technologies Work Programme 2007* that the MIMOMEMS project addresses



B3.1 Strategic impact

MIMOMEMS will contribute towards each of the expected impacts detailed for REGPOT-2007-1:



Thank you !